Fly Ash Carbon Separation and Ammonia Removal at Tampa Electric Big Bend

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KEYWORDS: Fly Ash, NOx, LOI, Fuel Recovery, Ammonia

ABSTRACT

Separation Technologies, LLC (ST) operates fly ash beneficiation facilities, processing poor quality fly ash into high quality pozzolanic material. ST’s triboelectric separation process reduces the carbon content of fly ash, producing ProAsh® a consistent, low loss on ignition (LOI) ash for use as a substitute for cement in concrete. Simultaneously a carbon rich product, EcoTherm™ is created that can be returned to the utility for recovery of the fuel value or to a cement kiln as both fuel and a source clinker material. ST also operates a process to remove excess ammonia from fly ash.

In 2008, ST commissioned its newest and largest US fly ash beneficiation facility at the Tampa Electric Company Big Bend Station in Florida. Two ST separators are installed to produce low LOI ProAsh®. A first-of-its-kind third separator is used to further concentrate the carbon to maximize the fuel value of the EcoTherm™ and to maximize the amount of ProAsh® recovered.

At Big Bend the ST ammonia process reduces the ash ammonia from average levels of ~2000 ppm to <75 ppm to meet market requirements. Improvements in this second commercial installation of the ST ammonia system include higher rate capability, improved drying efficiency, and use of a catalytic system to recover heat by converting the liberated ammonia gas into nitrogen. The Big Bend facility, which will produce 260,000 tons per year ProAsh® includes a 25,000 ton dome for feed ash, a 10,000 ton silo for ProAsh® and a 6,500 ton silo for EcoTherm™.

ProAsh® and EcoTherm™ are produced with ST’s technology at eleven power stations throughout the U.S., Canada and the United Kingdom.

ST Tampa Big Bend Facility

In designing the Big Bend facility, ST’s principle goal was build an energy efficient facility to capture 100% of the fly ash produced by the power plant while maximizing the quantity of ProAsh® and the LOI content of EcoTherm™. While the storage domes installed at other ST facilities are used for ProAsh® storage to allow continued processing in the winter months when demand for concrete is low, the 25,000 ton
storage dome at the Big Bend facility is used for raw, unprocessed fly ash from the power plant. This large reserve of raw material allows the best optimization of installed separator capacity while maintaining a supply of processed ash during power plant shutdowns. In order to reduce the facility power consumption, energy efficient dense-phase ash conveying systems are used. Also, an array of solar cells is installed to generate electricity sufficient to supply the ST separator high voltage requirements. A schematic drawing of the complete ST facility at the Big Bend station is shown in Figure 1.

Figure 1: ST Process Schematic at TECO Big Bend Station
Two ST separators are used for processing of the raw ash, producing low carbon ProAsh® material. In the ST separator (Figure 3), material is fed into the thin gap between two parallel planar electrodes. The particles are triboelectrically charged by interparticle contact. The positively charged carbon and the negatively charged mineral are attracted to opposite electrodes. The belt moves the particles adjacent to each electrode toward opposite ends of the separator. The high belt speed also enables very high throughputs, up to 40 tons per hour on a single separator. The small gap, high voltage field, counter current flow, vigorous particle-particle agitation and self-cleaning action of the belt on the electrodes are the critical features of the ST separator.

By controlling various process parameters, such as belt speed, feed point, and feed rate, the ST process produces low LOI fly ash at carbon contents of less than 4% from feed fly ashes ranging in LOI from 4% to over 25%. The process is entirely dry, requires no additional materials other than the fly ash and produces no waste water or air emissions. The recovered ProAsh® consists of fly ash reduced in carbon content (LOI) to levels suitable for use as a pozzolanic admixture to replace a portion of cement in concrete production.
The ST separator is relatively compact. A machine designed to process up to 40 tons per hour is approximately 30 ft. (9.1 m) long, 5 ft. (1.5 m) wide, and 9 ft. (2.7 m) high. The required balance of plant consists of systems to convey dry fly ash to and from the separators.

Figure 3: Carbon Separator
Recovered Fuel Value of High-Carbon Fly-Ash

The ST separation process also recovers the otherwise wasted unburned carbon in the form of carbon-rich fly ash, branded EcoTherm™. EcoTherm™ has significant fuel value and can easily be returned to the power plant using the ST Carbon Return™ system to reduce the overall coal use at the plant. When EcoTherm™ is injected directly into the utility boiler, the energy from combustion is converted to high pressure/high temperature steam and then to electricity at the same efficiency as coal, typically 35%. The conversion of the recovered thermal energy to electricity in Separation Technologies Carbon Return™ system is two to three times higher than that of the competitive technology where the energy is recovered as low grade heat in the form of hot water which is circulated to the boiler feed water system. ST’s Constellation Power Source Brandon Shores, SMEPA R.D. Morrow, NBP Belledune, RWEnpower Didcot, EDF Energy West Burton, and RWEnpower Aberthaw plants, all include Carbon Return™ systems.
At Big Bend, a third carbon separator is dedicated to a second-stage processing of the high-carbon material from the 1st stage separation. The objective of this second pass operation is to increase the LOI of the high carbon stream and control the LOI of the EcoTherm™ within a narrow range (45-50%). A by-product of this second stage separation is ash containing approximately the same LOI level as the original raw ash (~8%). This ash is returned to the feed ash bins of the first-pass separators. Recycling this second stage–low carbon ash allows the optimization of the 1st stage systems to maximize the amount of ProAsh® generated for use in the production of concrete.

The EcoTherm™ produced in the second stage is utilized at cement kilns as both a fuel substitute for coal and as a source of mineral required for adjusting cement clinker chemistry. EcoTherm™ can displace a large portion of the required fuel to a kiln as well as minimize the need for bauxite as an alumina source. Utilizing the high carbon EcoTherm™ ash either at a power plant or a cement kiln, maximizes the energy recovery from the delivered coal, reducing the need to mine and transport additional fuel to the facilities. Big Bend EcoTherm™ contains approximately 45% carbon and will be utilized at nearby cement kilns as both fuel and a source of alumina. By assuring a minimum level of carbon, and thus fuel value, this high carbon EcoTherm™ can be better utilized at the cement kiln on a routine basis.

**Removal of Ammonia from Fly Ash**

The fly ash at Big Bend is contaminated with ammonia due to the injection of ammonia into the power plant’s ESP systems to control the emission of SO₃ aerosol generated by the SCR NOx control system. At other power plants, ammonia contamination also occurs with SNCR NOx control and the use of ammonia to enhance particle collection in ESP systems. While ammoniated ash is not detrimental to concrete performance, when the ammoniated ash is mixed with the alkaline cement in production of concrete, the ammonia is volatilized. The released ammonia presents a hazard to workers both at the concrete plant and during placement and finishing of the concrete. Ammonia can also be released from cured concrete at low levels upon repeated wetting of the concrete, causing an unpleasant, though non-hazardous condition. Generally, fly ash containing greater than 100 mg/kg of ammonia is considered unacceptable for production of concrete.

At Big Bend, the fly ash ammonia levels for units with ammonia injection range from 750 to 3360 mg/kg ammonia. Consequently, the ProAsh® must be treated by the ST ammonia removal process. Figure 5 shows a flow diagram of the ST ammonia system. To remove ammonia as a gas from the fly ash, the ST process utilizes the same fundamental chemical reaction that results in ammonia release in concrete. Key features of the ST process are the use of a minimum quantity of water (1 to 3%, typically 2%) and minimal quantities of alkali (< 3%). The deammoniated ash is dried by conveying the material through a flash drier to remove excess water. Drying requires relatively little energy due to the minimal moisture addition required by the process.
The design of the ST ammonia removal process installed at Big Bend is the second full scale installation and includes many refinements. Material handling equipment is improved to allow operation at higher rates. The drying system is downsized from the previous design and includes recycling of hot gases to reduce the overall energy requirements of the system. Lastly, the ammonia released in the process is fed to a two-stage catalytic unit where the collected ammonia gas is converted into nitrogen. The heat generated by this reaction is recovered and used to supplement the energy requirement of the fly ash flash drying system. The use of the two-stage catalytic system results in minimal NOx emissions.

The process recovers 100% of the fly ash treated and the resulting ash meets all specifications for use in concrete. ST’s ammonia removal process can be used alone or in combination with the company’s carbon separation technology. The carbon separation process is not affected by the presence of ammonia. This modular approach offers the lowest cost solution for treating otherwise unusable fly ash.

Figure 5: ST Ammonia Removal Process
This commercial scale operation can handle up to 52 tons per hour of contaminated ash, reducing the ammonia content to less than 75 mg/kg. Ammonia levels of the incoming fly ash vary from ~750 to 3300 mg/kg. The process is very robust, resulting in 97+% ammonia removal, producing ash well below our target of maximum 100 mg/kg ammonia. Final moisture contents are <0.5%. Full-scale ST ammonia removal systems are operating at Jacksonville Electric Authority SJRPP, TEC Big Bend, and RWE npower Aberthaw ash processing facilities.

**ST Ash Processing Facilities**

ProAsh\textsuperscript{\textregistered} and EcoTherm\textsuperscript{™} are produced with ST's technology at eleven power stations throughout the U.S., Canada and the United Kingdom. ProAsh\textsuperscript{\textregistered} has been approved for use by over twenty state highway authorities, as well as many other specification agencies. ProAsh\textsuperscript{\textregistered} has also been certified under Canadian Standards Association and EN 450:2005 quality standards in Europe. ST ash processing facilities are listed in Table 1.
<table>
<thead>
<tr>
<th>Utility / Power Station</th>
<th>Location</th>
<th>Start of Commercial operations</th>
<th>Facility Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constellation Power Source Generation - Brandon Shores Station,</td>
<td>Maryland</td>
<td>April 1999</td>
<td>2 Separators 35,000 ton storage dome. Carbon Return™ 2008</td>
</tr>
<tr>
<td>ScotAsh (Lafarge / Scottish Power Joint Venture) - Longannet Station</td>
<td>Scotland</td>
<td>Oct. 2002</td>
<td>1 Separator,</td>
</tr>
<tr>
<td>Jacksonville Electric Authority - St. John’s River Power Park, FL</td>
<td>Florida</td>
<td>May 2003</td>
<td>2 Separators Coal/Petcoke blends Ammonia Removal</td>
</tr>
<tr>
<td>South Mississippi Electric Power Authority R.D. Morrow Station</td>
<td>Mississippi</td>
<td>Jan. 2005</td>
<td>1 Separator Carbon Return™</td>
</tr>
<tr>
<td>New Brunswick Power Company Belledune Station</td>
<td>New Brunswick, Canada</td>
<td>April 2005</td>
<td>1 Separator Coal/Petcoke Blends Carbon Return™</td>
</tr>
<tr>
<td>RWE npower Didcot Station</td>
<td>England</td>
<td>August 2005</td>
<td>1 Separator Carbon Return™</td>
</tr>
<tr>
<td>PPL Brunner Island Station</td>
<td>Pennsylvania</td>
<td>December 2006</td>
<td>2 Separators 40,000 Ton storage dome</td>
</tr>
<tr>
<td>Tampa Electric Co. Big Bend Station</td>
<td>Florida</td>
<td>April 2008</td>
<td>3 Separators, double pass 25,000 Ton storage dome Ammonia Removal</td>
</tr>
<tr>
<td>RWE npower Aberthaw Station (Lafarge Cement UK)</td>
<td>Wales</td>
<td>September 2008</td>
<td>1 Separator Ammonia Removal Carbon Return™</td>
</tr>
<tr>
<td>EDF Energy West Burton Station (Lafarge Cement UK, Cemex)</td>
<td>England</td>
<td>October 2008</td>
<td>1 Separator Carbon Return™</td>
</tr>
<tr>
<td>HATRA Cement i Beton (Lafarge Cement Poland / Ciech Janikosoda JV))</td>
<td>Poland</td>
<td>Under Constr., Startup early 2010</td>
<td>1 Separator</td>
</tr>
</tbody>
</table>
Summary

The Separation Technologies' beneficiation processes continue to be the most extensively applied methods to upgrade otherwise unusable fly ash to high value materials for cement replacement in concrete and enabling the utilities to avoid disposal costs. Seventeen ST carbon separators are in place with over 75 machine-years of operation. The ST processed ash, ProAsh®, has found wide acceptance in the concrete industry as a premium fly ash requiring far less monitoring of air entrainment requirements due to less LOI variability than other ashes. Reintroducing the high-carbon concentrate, EcoTherm™, from the ST process into the fuel mix at a power plant allows recovery of the material's fuel value at an efficiency similar to coal. In addition to the fuel value, use of EcoTherm™ in cement kilns provides valuable minerals such as alumina, silica and iron that are required for clinker production. With the additional availability of the ammonia process, ST offers commercially economical means to recover material for high value use that would otherwise be landfilled. Electrostatic carbon separation, Carbon Return™, and ammonia removal processes provide a modular solution to a utility's fly ash needs. These three processes can be implemented in phases, or as a single project.